Uncovering luminous and highly obscured AGN with Mid-InfraRed surveys

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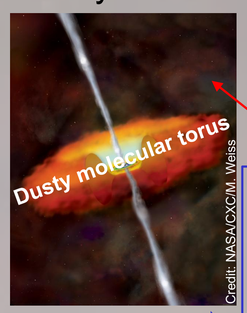
Abstract

We present the results of a detailed analysis of the X-ray properties of a complete, mid-IR 12 microns flux-limited sample, of 97 luminous AGN candidates selected with WISE. The full 6 deg^2 survey area has very deep X-ray coverage from *XMM-Newton* observations, reaching X-ray fluxes of just 10^{-15} erg/cm^2/s. To date 92 objects have spectroscopic redshifts and optical classifications. Thus, we can evaluate the reliability and effectiveness of WISE to uncover luminous, highly obscured systems. Moreover, we can provide independent estimates of the space density of obscured accretion up to redshift one, which can be compared with the results derived from wide-area, and shallower, X-ray surveys. We also discuss the prospects of detecting with Athena the 24% of the sample yet undetected with *XMM-Newton*.

Motivation

- An unbiased census of AGN is sorely needed:
  - The most highly absorbed AGN still evade our census
  - The space density and contribution from Compton Thick objects (N_H>1.5 × 10^{24}cm^{-2}) to the total AGN population is uncertain

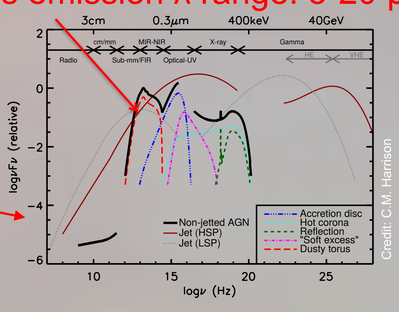
Can mid-IR (MIR) searches identify the elusive highly obscured AGN missed at other wavelengths?

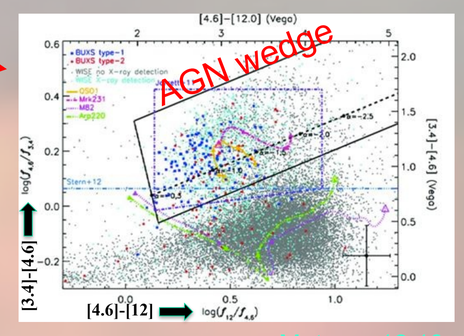


MIR searches for AGN

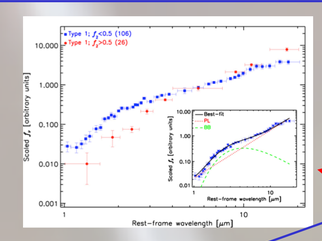
- The circumnuclear obscuring dust re-emits the AGN radiation at MIR wavelengths
- MIR surveys much less affected by obscuration than optical/Xray surveys
  - Almost unbiased selection of highly obscured AGN (Mateos+12,13; Assef+13,18)
- Based on MIR colours from WISE
  - AGN have red power-law continuum: $f_\nu \propto \nu^\alpha$ with $\alpha \leq -0.5$ (Alonso-Herrero+06) ⇒ AGN wedge

Torus emission λ range: 3-20 μm



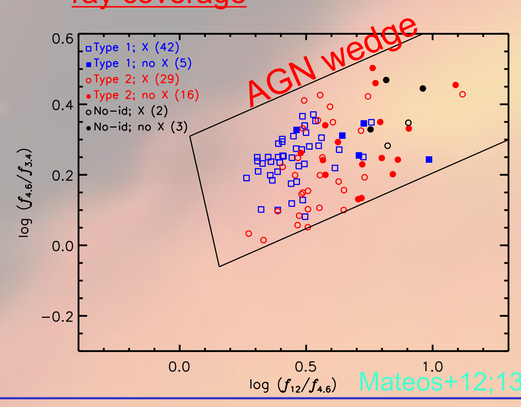


Mateos+12,13



Uncovering highly absorbed AGN with WISE

- Pilot study:
  - 12 μm flux limited sample ($f_{12\ \mu m}$ **>** 1mJy)
  - 97 mid-IR selected AGN candidates
  - 95% optical spectroscopic identification rate (follow-up at GTC, WHT)
  - 5 deg^2 of BUXS sky area with deep X-ray coverage



Mateos+12;13

Confirmation of AGN nature

- 97 MIR-selected AGN candidates:
  - 47 optical type 1 AGN (49%)
  - 45 optical type 2 AGN (46%)
    - >2keV X-ray detection and/or $L_{2\text{-}10\ keV}$>10^{42} erg s^{-1}: 30
    - BPT+ [NeV]-detection: 5
    - IR SED decomposition: AGN dominant at rest-frame 6μm (>50%): 8
  - 5 sources unidentified
    - >2 keV X-ray detection: 3
    - **2 sources remain as AGN candidates (unidentified)**

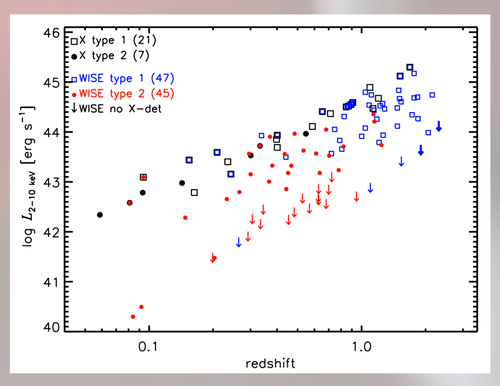
<12% contamination of MIR sample ⇒ High reliability of MIR selection

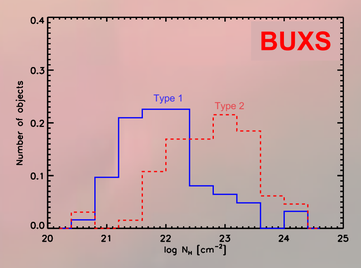
Properties of MIR-selected AGN

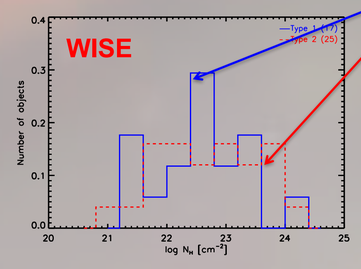
- 28 BUXS sources in 5 deg^2 area of our MIR survey
- BUXS X-ray flux limit >50 higher than for our WISE sample

Substantial fraction of luminous AGN missed by flux limited X-ray surveys

It could be even higher considering the non-X-ray detections (21.6% of the sample)







X-ray absorption

- 72 sources with X-ray spectroscopic data

MIR surveys are revealing a population of moderate luminosity, highly obscured type 1 and type 2 AGN at z<1

Revealing the most highly absorbed AGN

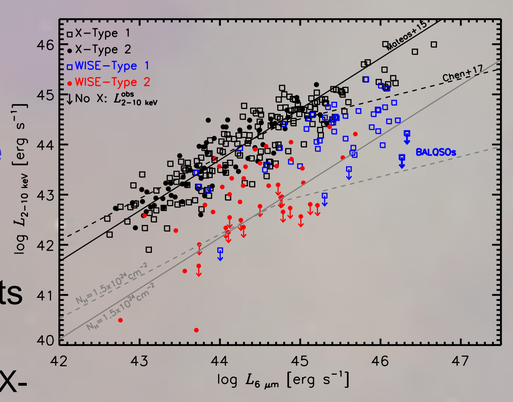
- $L_{6\ \mu m}$ as tracer of intrinsic AGN power (L_{bol})

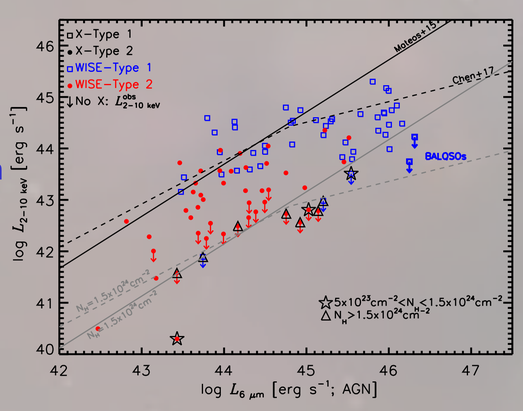
Mid-IR-selected AGN preferentially below the $L_{2\text{-}10\ keV}$ vs. $L_{6\ \mu m}$ relation (even after correction for star formation)

- Estimating column densities for X-ray upper limits
  - $L_{6\ \mu m} \Rightarrow L_{2\text{-}10\ keV}$
  - Comparing this expected $L_{2\text{-}10\ keV}$ with the observed X-ray flux upper limit from XMM-Newton images
  - ⇒ lower limit in N_H
  - 8 highly absorbed AGN (N_H~10^{24} cm^{-2}) and 3 Compton-thick AGN (N_H>10^{24} cm^{-2})

Many highly obscured AGNs not detected with contemporary wide-angle X-ray surveys

(see also Donley+12)





Detection of the faintest sources

- With *XMM-Newton* they would all take >100ks and up to several Ms
- *Athena* will be ESA's next-generation state-of-the-art X-ray observatory in the early 2030s
  - Estimated exposure times needed with Athena/WFI
  - Most would require ≲50ks and all require ≲90ks for detection
  - Well within the depth of the "shallow" wide tier of the Athena survey

They will all be detectable with Athena with moderate exposure times